Sammenligning af designmetoder for møller i wake

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Comparison of Design Loads for Turbines in Wake

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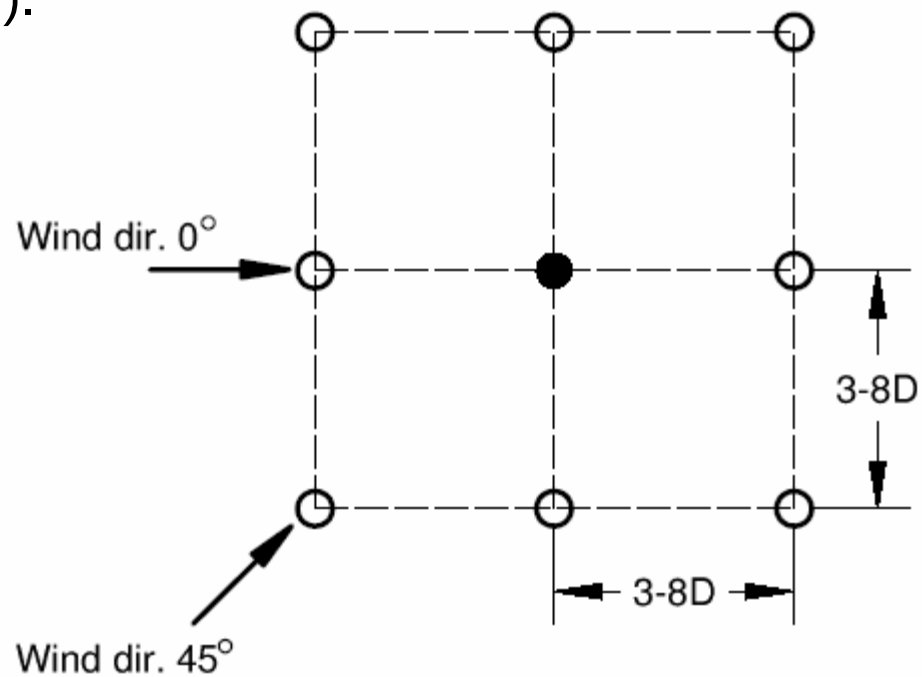
What is done?

- A new implementation of the DWM method is implemented i HAWC2, which is capable of calculating the velocity deficit for the downstream distance, the meandering path, and added wake turbulence for as many neigbouring turbines as desired.
- A study is performed where the fatigue and ultimate loads from the DWM model is compared with the IEC method (MET method by Sten Frandsen).



Simulation for each 2 deg using 6 seeds.

Total of 3312 DWM 10min. simulations

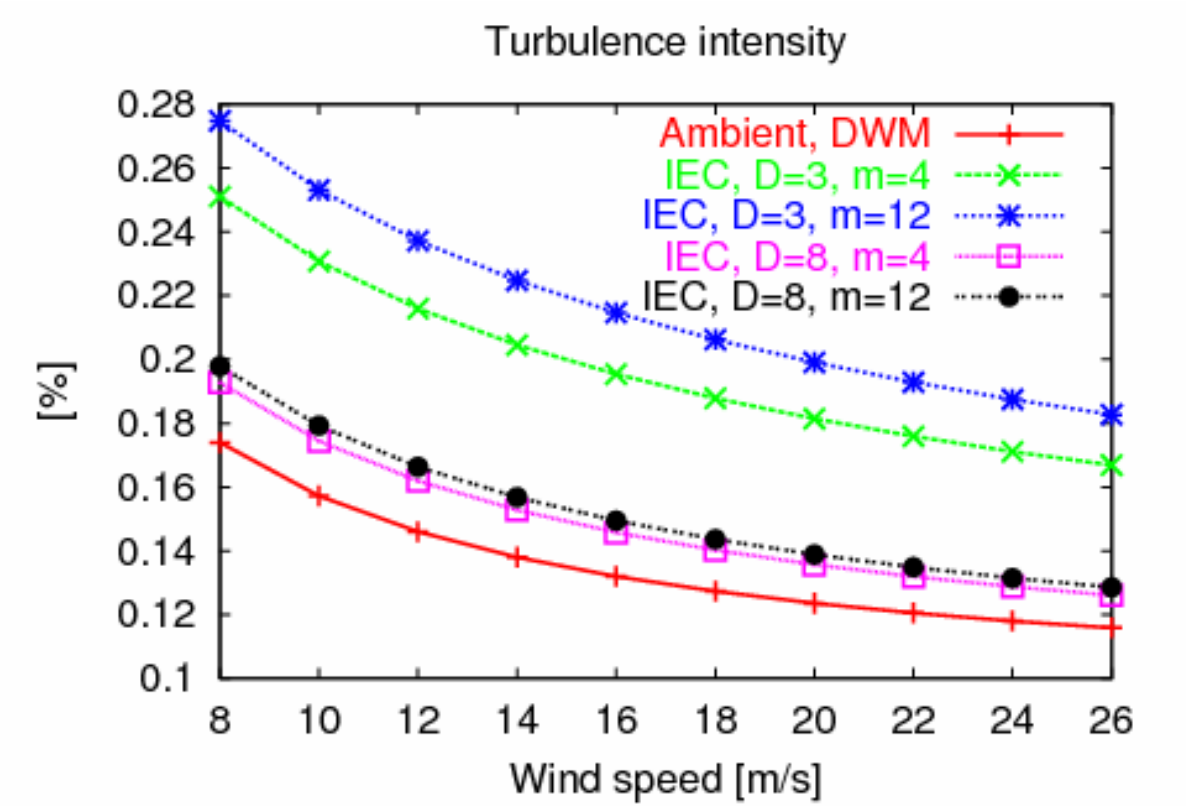
The method from IEC61400-1 ed. 3: Equivalent Turbulence

$$I_{eff} = \frac{1}{V_{hub}} \left[(1 - N p_w)\sigma^m + p_w \sum_{i=1}^{N} \sigma_T^m d_i \right]^{\frac{1}{m}} \quad (1)$$

$$\sigma_T = \sqrt{\frac{0.3 V_{hub}}{1.5 + 0.3 d_i \sqrt{\frac{V_{hub}}{c}}} + \sigma^2} \quad (2)$$

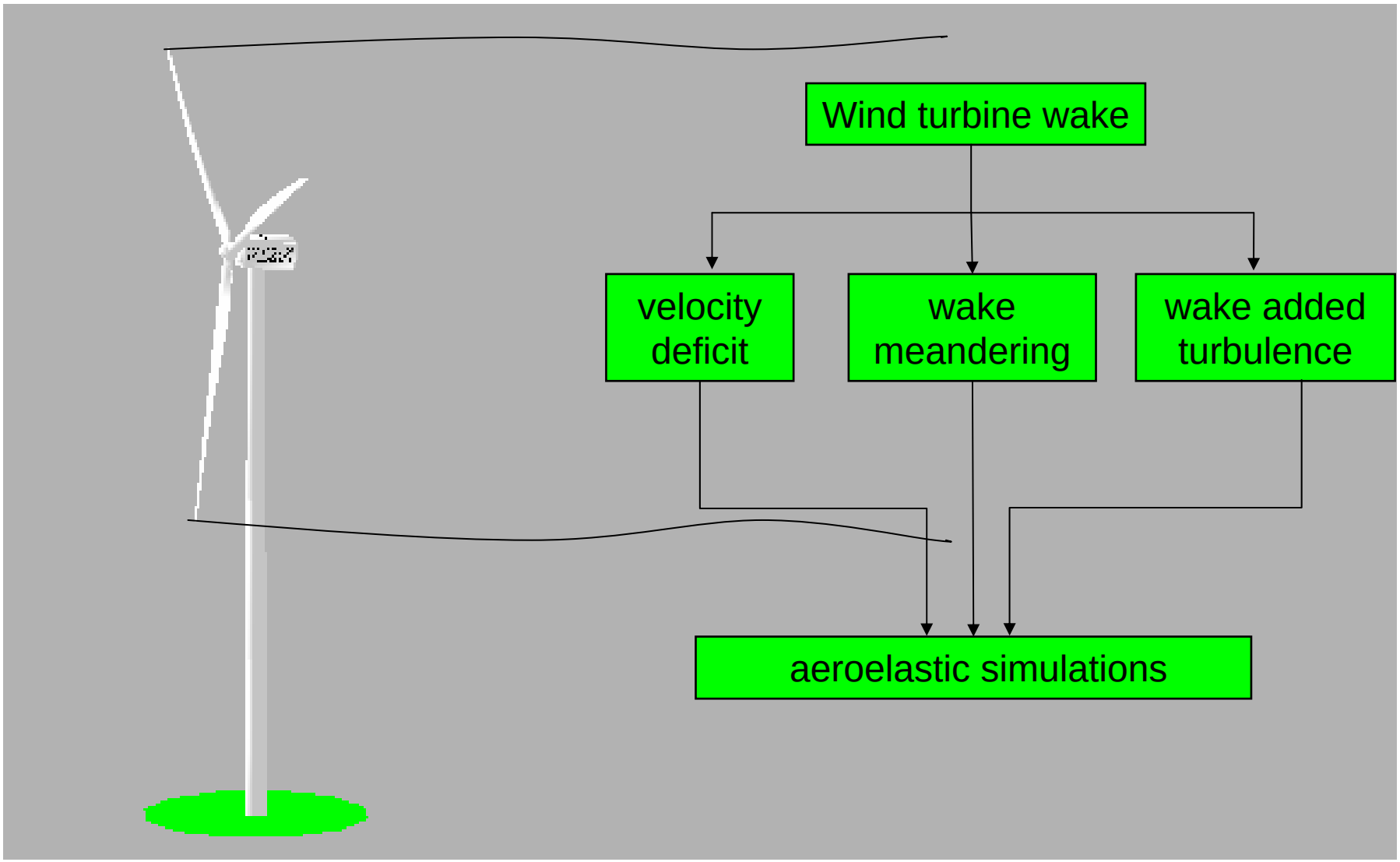
The used turbulence is increased to a higher level calibrated to give the right fatigue level for the observed component.

Used turbulence intensity for the IEC method

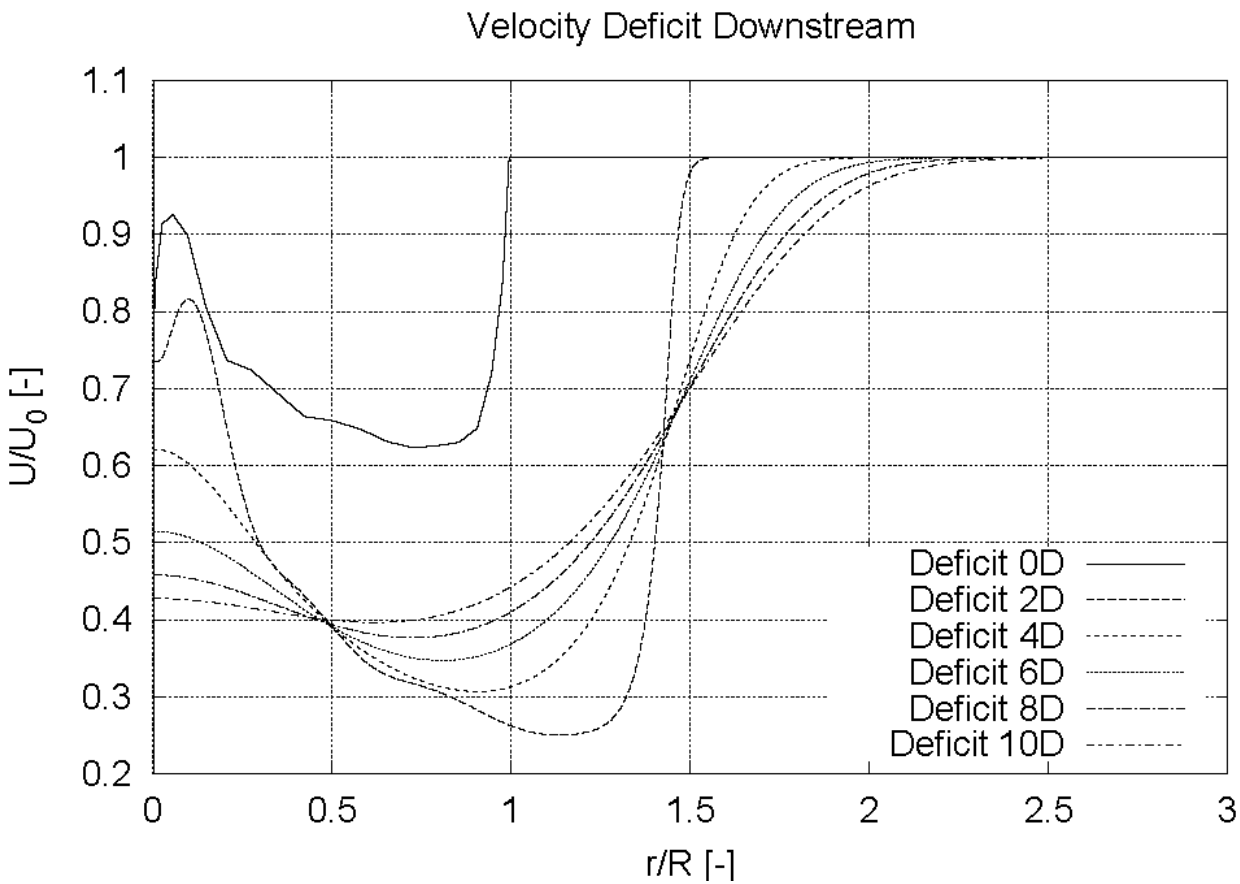


Ambient turbulence corresponds to class IC
(high wind low turbulence)

The DWM model



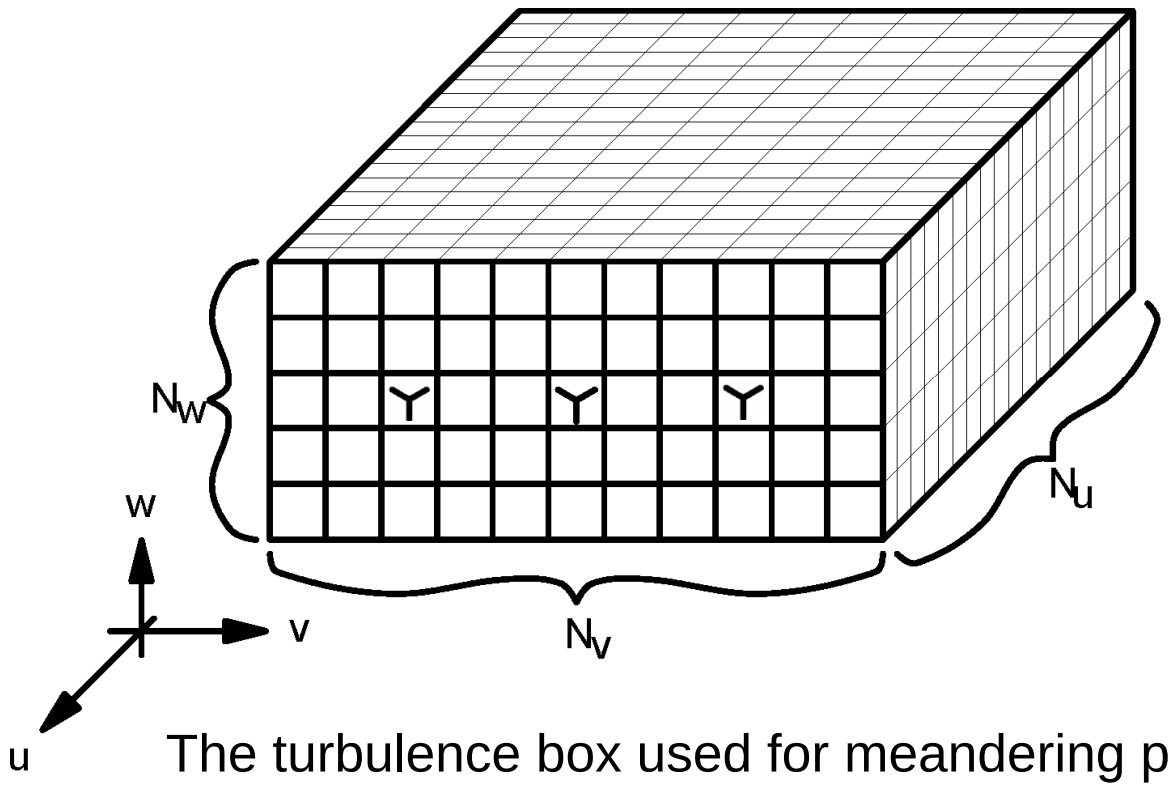
Deficits used



Method how the deficit are derived are described in detail by Madsen et al. in ”The DWM wake model compared with the ACL wake model and measurements” EWEC 2008, Brussels

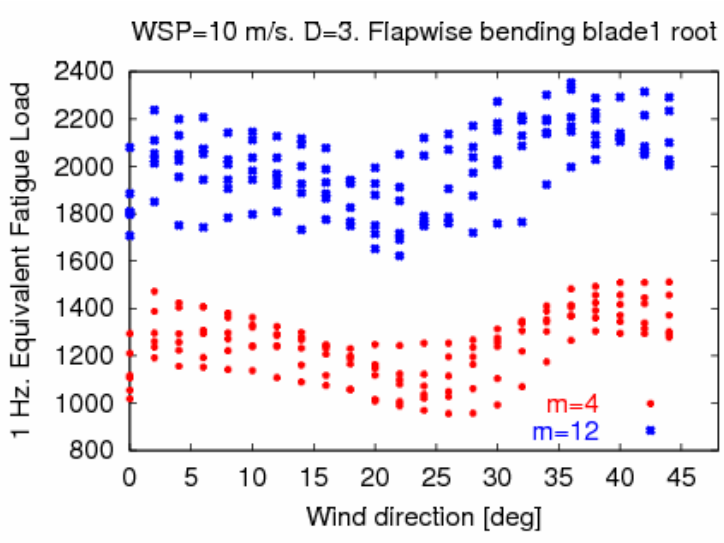
The Meandering

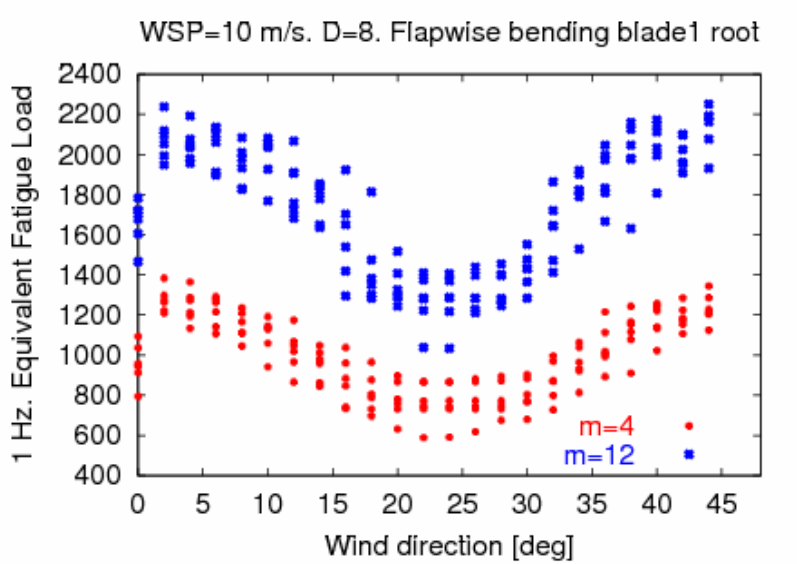
- A cascade of wake deficits are released from the upstream turbine
- Each deficit will be transported dowstream affected only by ambient large scale turbulence (like smoke from a chimney)

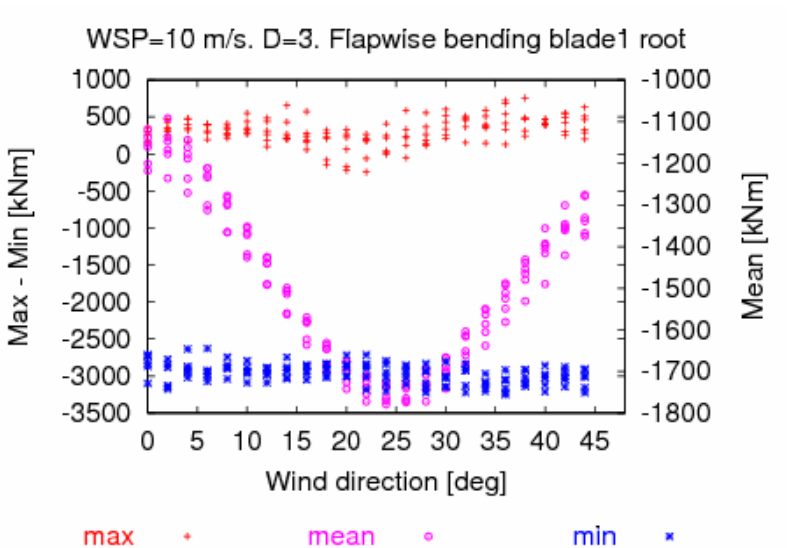


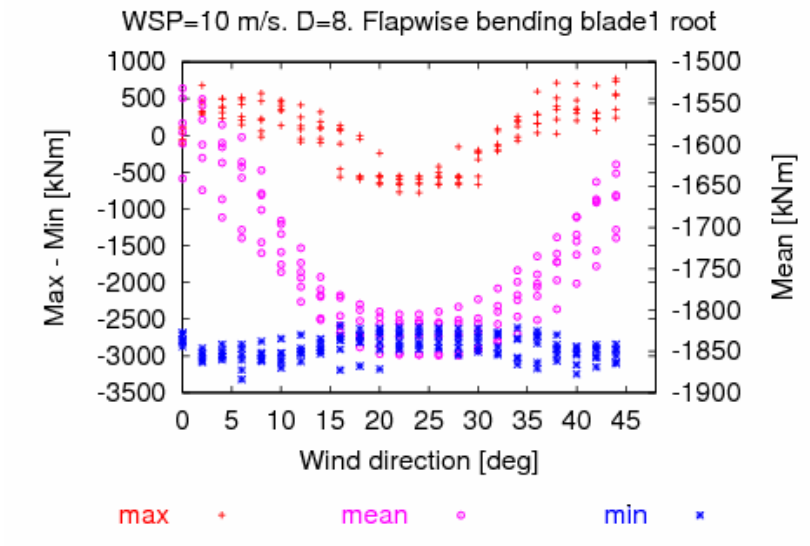
The turbulence box used for meandering path calculation

Influence from wind direction: Flapwise blade bending

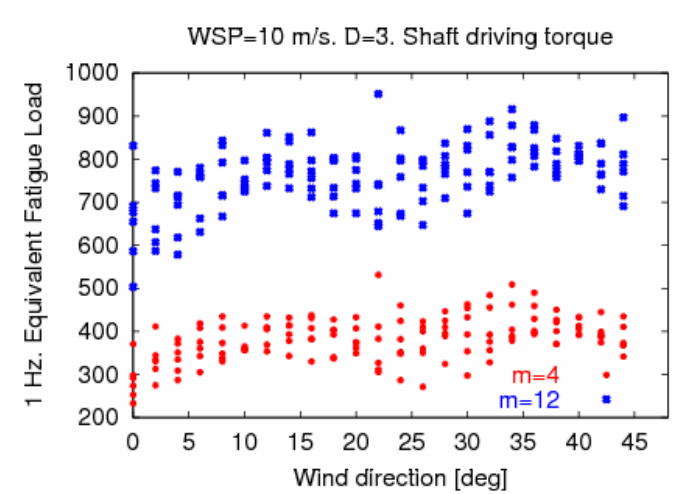


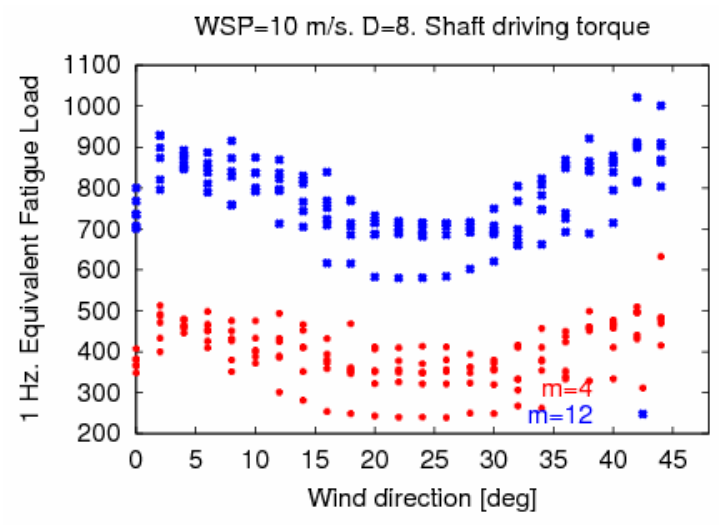


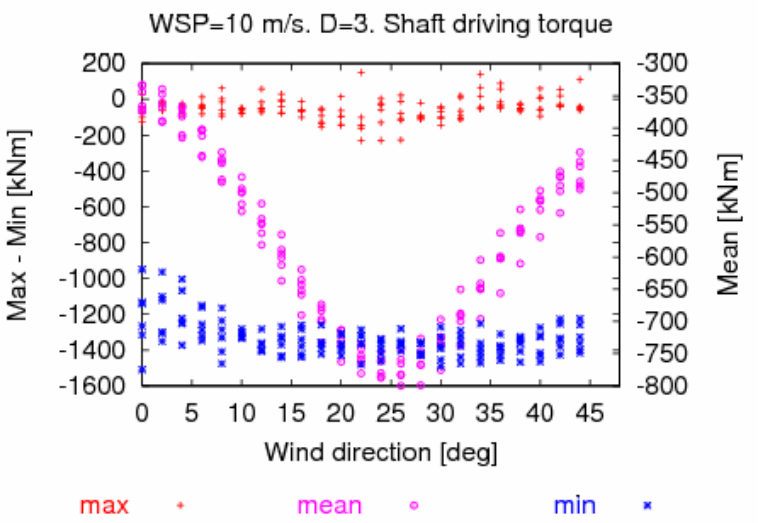


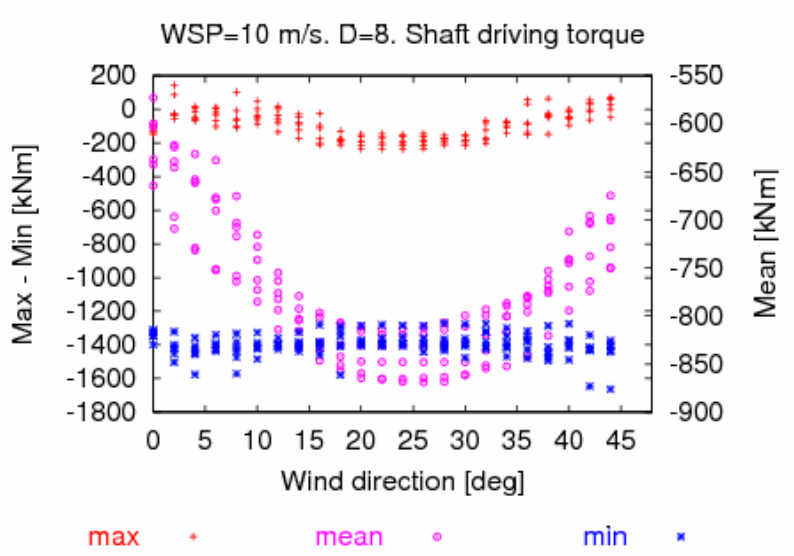


Influence from wind direction: Driving torque

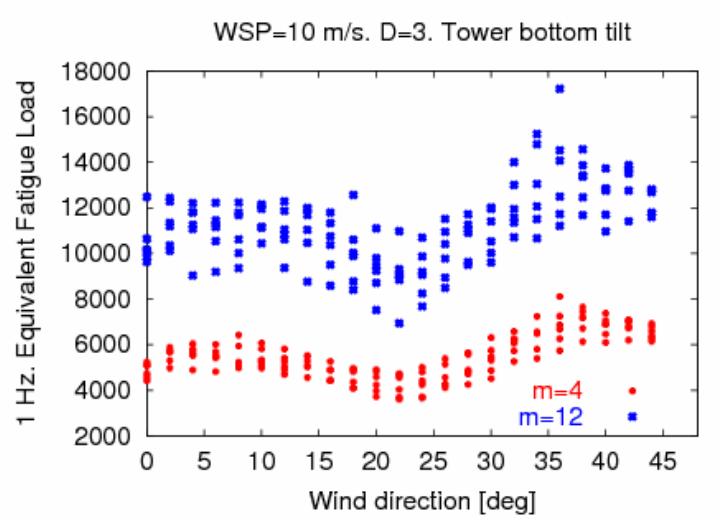


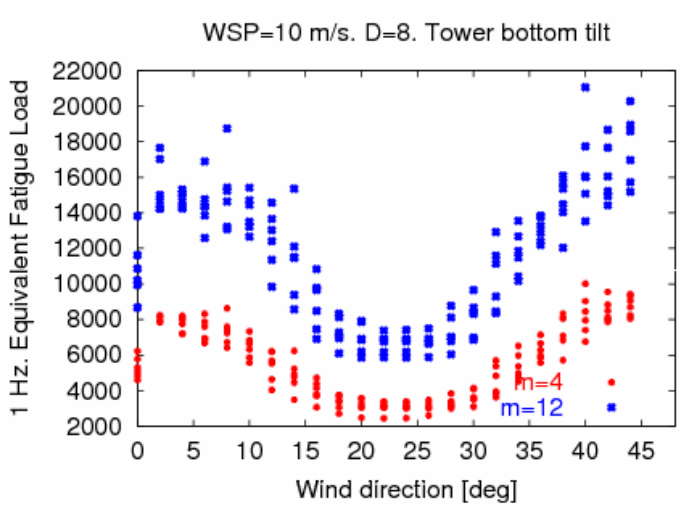


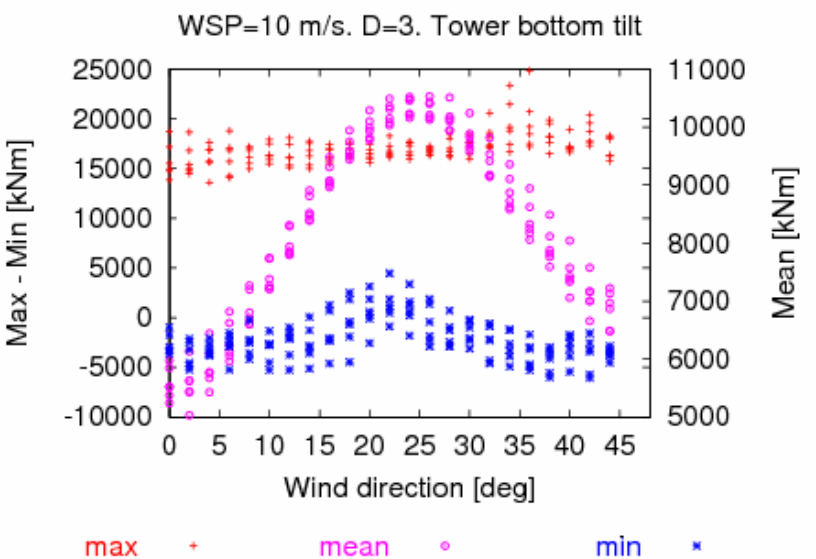


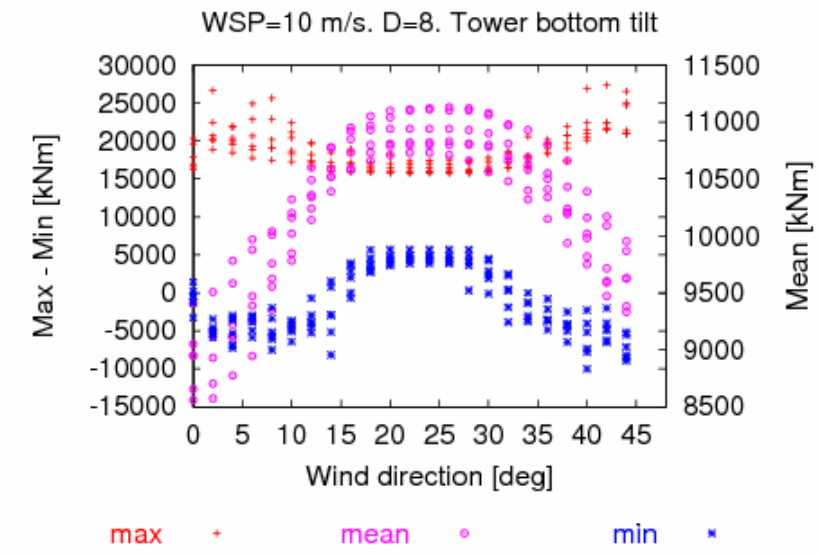


Influence from wind direction: Tower bottom tilt

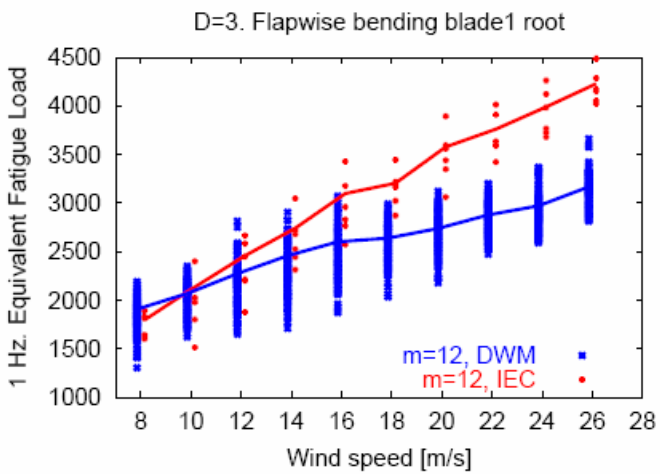


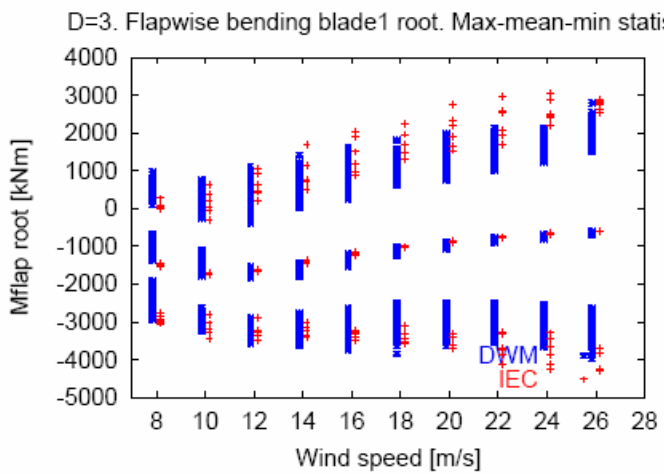


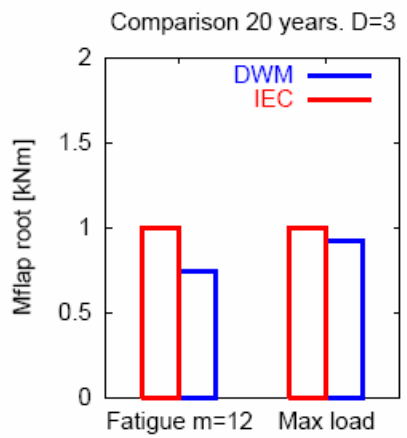


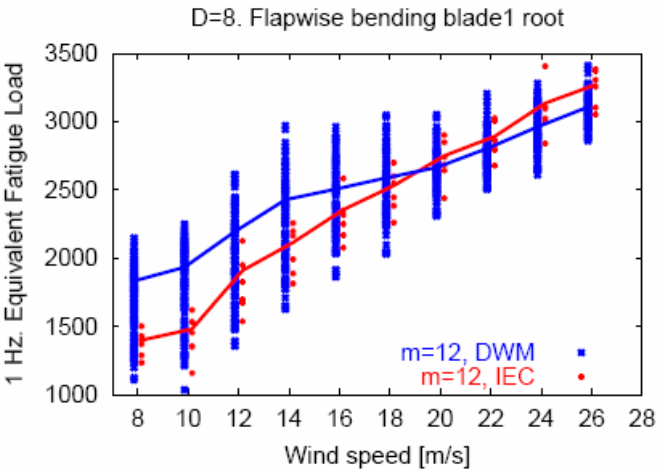


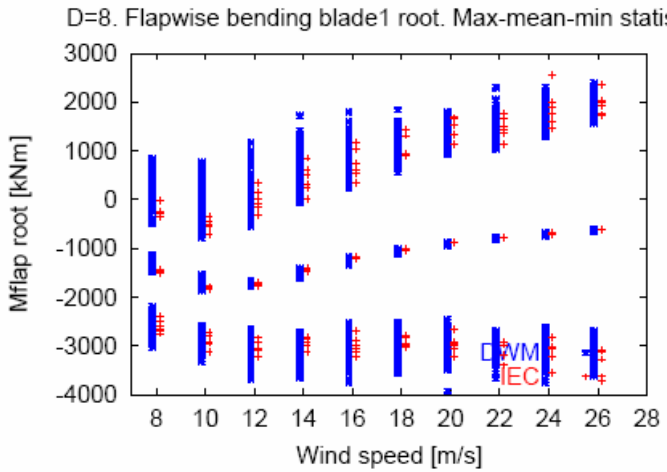
DWM – IEC Comparison: Flapwise blade bending

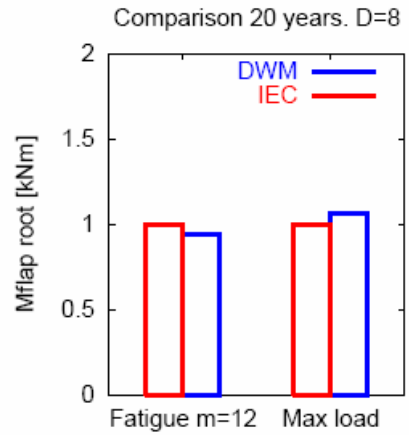




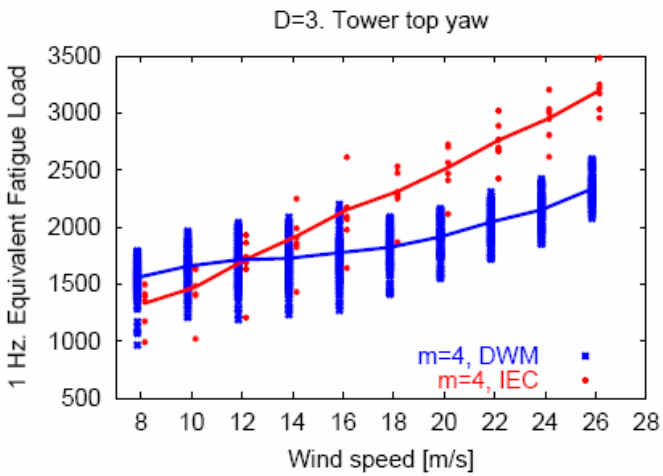


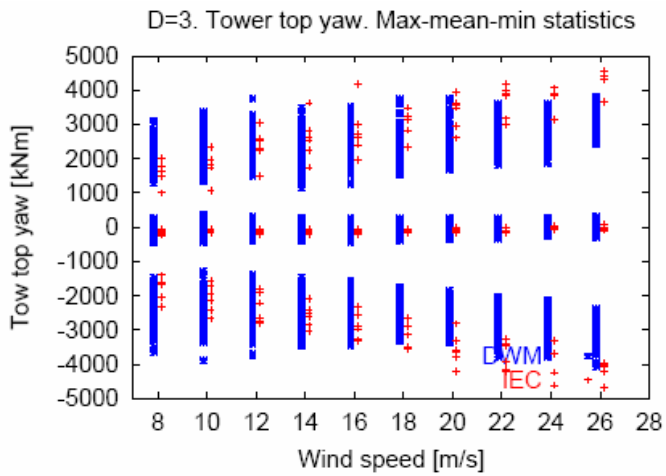


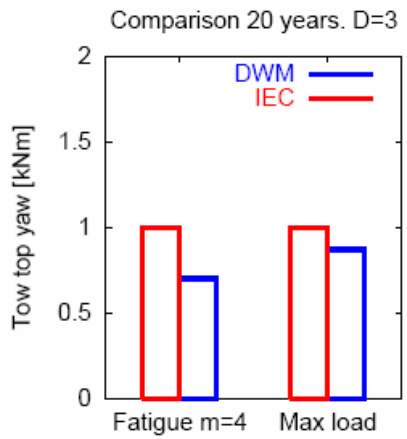


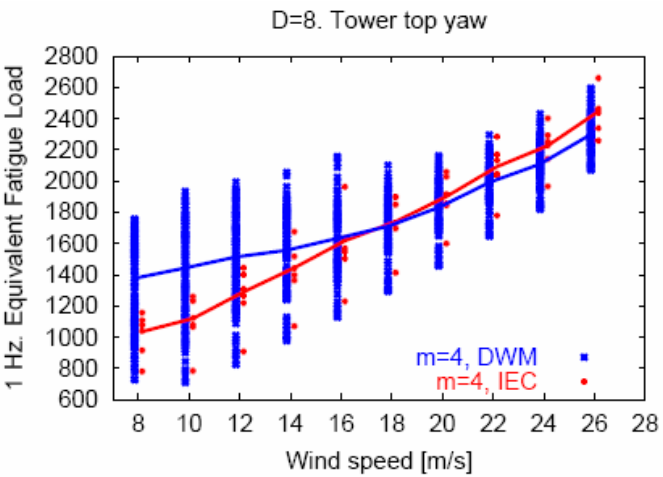


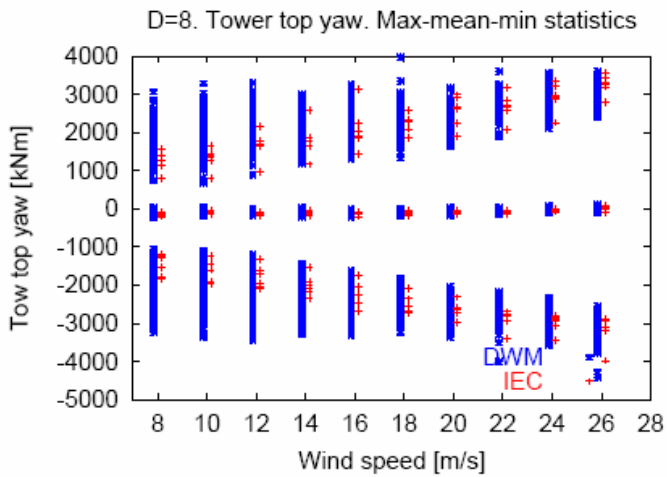
DWM – IEC Comparison: Yaw bearing moment

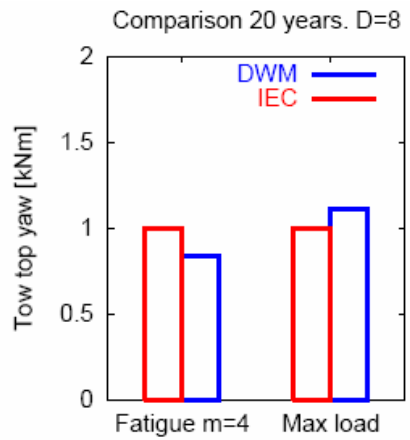




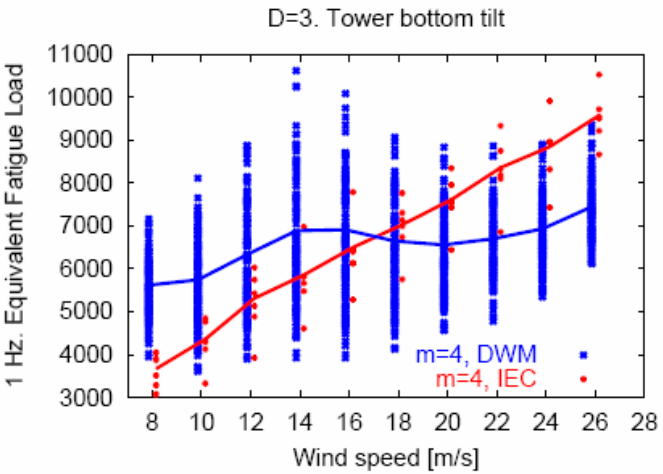


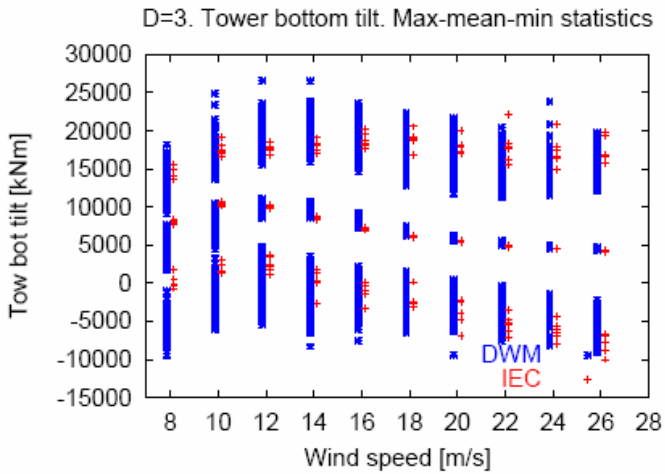


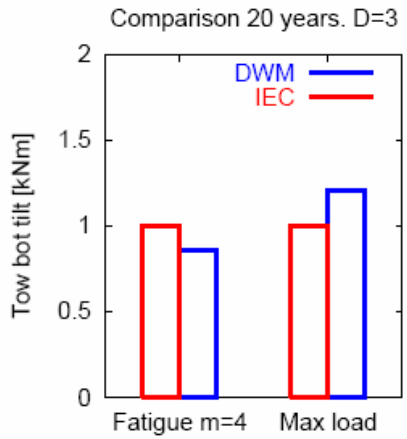


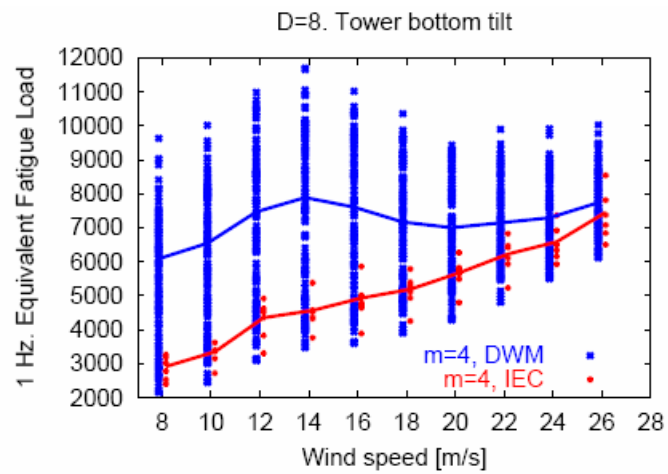


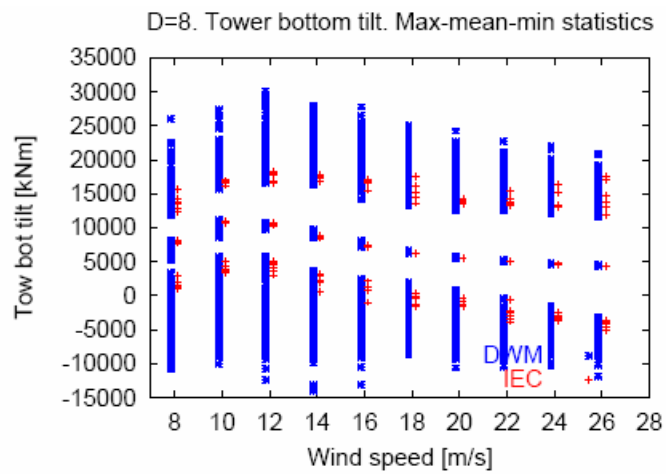
DWM – IEC Comparison: Tower bottom tilt

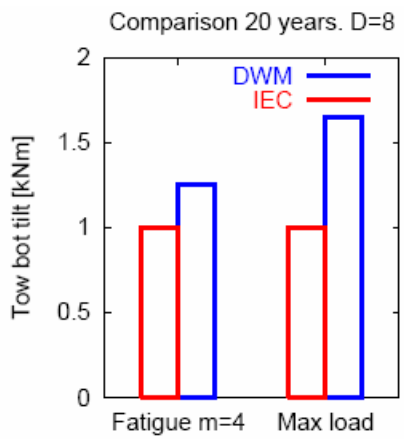




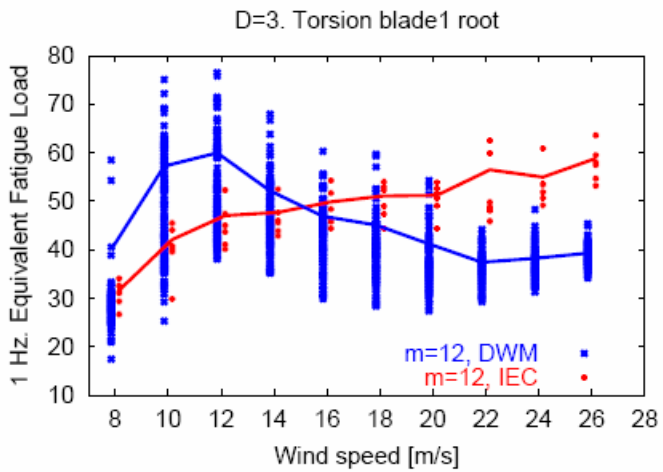


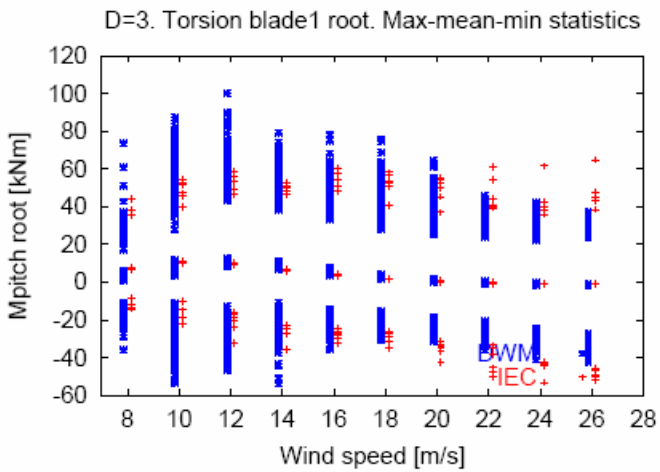


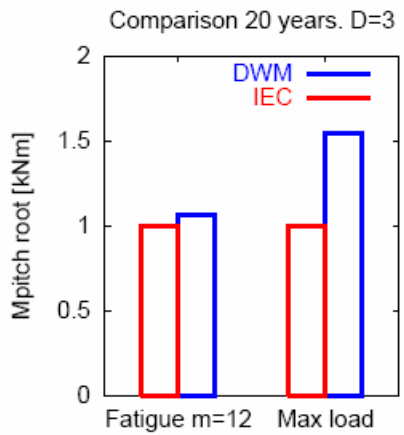


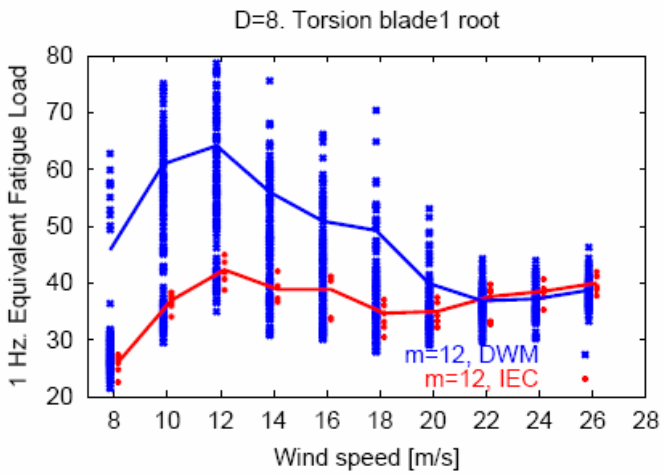


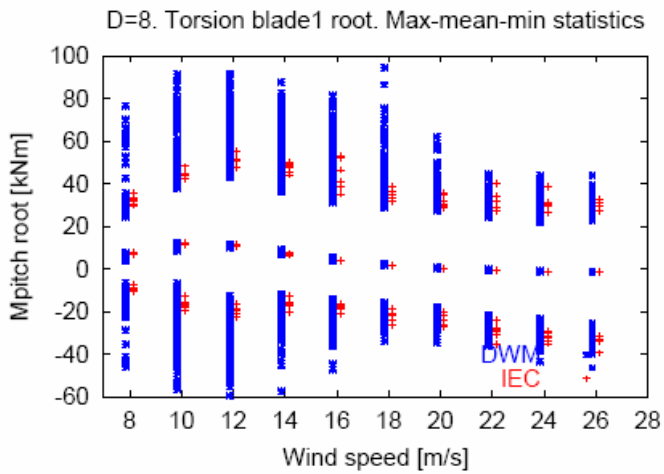
DWM – IEC Comparison: Blade torsion

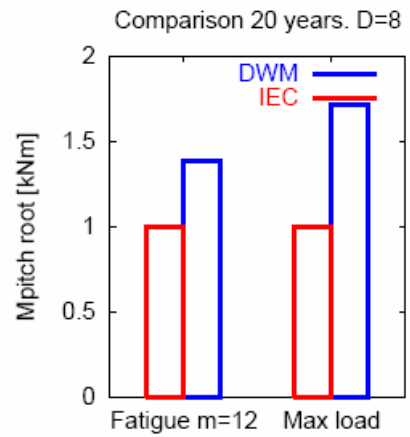












Conclusion

- New improved implementation of DWM model in HAWC2 demonstrated.
- In the used square grid park configuration the turbine *never experiences free flow direction at 3D spacing*.
- *Tower loads increase with increased row distance*. (At least up to 8 diameters spacing.) Possible explanation is the meandering effect.
- For 3D spacing the IEC loads are conservative regarding flapwise blade bending, for the yaw, driving torque and flapwise bending, whereas the loads on tower and blade torsion are non-conservative. Max load for tower +20% and blade torsion +55%
- For 8D spacing there is good agreement between the two models regarding yaw, driving torque and flapwise blade bending. A significantly higher load level is seen with the DWM model regarding tower loads and blade torsion. Fatigue +25% and max. load +60% for tower and blade torsion.